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Energy trends in Palestinian territories of West Bank and Gaza Strip: Possibilities for reducing the reliance on external energy sources

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ABSTRACT

The Palestinian territories (PT) is dependent on external sources to meet their energy demands. Around 80% of their energy sources come from neighboring countries. This dependency renders the price of different fuel types, despite the fact that the per capita consumption is among the lowest. The goal of this work is to reduce the energy dependency on external energy sources, with the express hope that a more stable and reliable energy security can be realized. This paper will attempt to detail the current energy demands in the PT, and evaluate the different possibilities in reducing the reliance on external energy sources. Adopting clear and transparent energy policies that result in strategies and action plans directed to encourage the exploitation of renewable energy is the first step in achieving this goal. Investments in renewable energy is one of these measures where PT have good potentials of solar radiation, huge amounts of biomass, good wind speeds at certain sites and success in utilizing geothermal energy for domestic applications. The analysis of a number of pilot projects being installed or are running in the PT for different renewable energy fields are indicative of their viability and potential in the context of the PT. The development of a clear energy conservation policy is also an important tool that can be used to reduce the energy consumption in the PT, which will in turn reduce the dependency of the PT on external energy sources.

Contents

Abbreviations: GS, Gaza Strip; IEC, Israeli Electrical Company; LPG, liquefied petroleum gas; NGOs, non-government organizations; PIF, Palestine Investment Fund; PT, Palestinian territories; PV, photovoltaic; TJ, tera Joule; WB, West Bank

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1. Introduction

Energy is essential to the livelihood of the people. Its availability is salient vis-à-vis the realization of welfare and sophistication in the standard of living of citizens, and forms the yardstick of economic success of a nation [1–6]. It is actually very important in accelerating the wheel of economy.

The economy of the Palestinian territories is severely underdeveloped due to the decades being under Israeli military occupation. During this period, the infrastructure of the PT was severely neglected, electricity being one of them. This, in fact, created different energy problems and impeded any real growth concerning different energy scenarios.

PT is divided into two territories: West Bank (WB) and Gaza Strip (GS). Fig. 1 shows the PT map. There is a lack of physical continuity between WB, GS and East Jerusalem, which is also a part of WB. Moreover, different portions in the PT suffer from military occupation, settlement activities and control. The land in WB is divided according to OSLO agreement into three types of areas: A, B and C, where most of the land is in area C. Any project in this area cannot be implemented without the express approval from the Israeli authorities. These insurmountable obstacles almost make it impossible to developing a reliable infrastructure for the energy sector and the related activities that are needed in relation to it.

For many years, different Palestinian communities suffered from dwindling or nonexistent energy resources. As a result of this, the economic development in these areas is adversely affected, while the price of energy skyrocketed relative to their adjacent neighbors. Moreover, attention to renewable energy and their utilization do not reach a satisfactory level, and the environmental pollution from conventional resources actually threatens different aspects of life. With the notable exception of solar water heaters, other applications in the renewable energy sector are very limited due to poor investments in this sector. In the electrical energy sector, the bulk of the electrical supply to the Palestinian territories comes from Israeli Electrical Company (IEC). This monopoly also affects the price of electricity, and creates shortages of electricity, with the threat of a future energy crisis looming over the horizon in the near future [7].

Quite a number of small remote communities in the PT lacks a source of electricity [7,8]. Connecting these communities to the available grid is difficult due financial and political constraints, since most of these communities are located in area C. Sometimes, diesel generators are used to electrify part of these communities for a limited period of time, mainly during the night. In addition to the high cost of generation, the gases emitted from these small diesel generators pollute the environment.

The different circumstances (economic, political, geographic, environmental and infrastructural) facing the energy sector in the PT, and the presence of natural resources required for the production of fossil fuels is rather limited, the development of the renewable energy sector to meet the increased requirements of energy demand is obviously advantageous and attract considerable interest. This sector has the potential to be effectively targeted by the investors.

This paper will attempt to detail the current energy policies, energy demand, environmental impacts for the production and consumption of energy, renewable energy in the PT, and the institutional and legal situation of the energy sector.

2. Energy demand

The area of the PT is 6020 km^2, whereas the area of WB is 5655 km^2, and the area of GS is 365 km^2 [9]. The majority of PT is surrounded by Israel. Other small portions of the boundaries (west boundary of GS with Mediterranean Sea and east boundary of Jericho with Jordan) are under actual Israeli control.

The PT is located in a transitional climatic zone between the Mediterranean and arid tropical zones. Climatic conditions of Palestine vary widely. There are three climatic zones in PT, which are coastal areas, hilly areas and Jordan valley. The coastal zone is mild (average of 15 °C) during winters, humid and hot (average of 24 °C) during summer, while hilly areas in WB are cold during winters, and mild in the summer. Jordan valley climate is warm and humid in winters, and hot and dry during summers. Temperatures in Jordan valley are always higher than coastal areas, while in hilly areas, they are usually low [9].

Palestine is a net importer of oil and petroleum products. Total energy consumption in the PT is considered the lowest in the region, while its costs are relatively high compared to its neighbors. The majority of this consumption goes to the residential sector. The largest portion of different types of imported fossil fuels consumed in PT originates from Israel, while the remainder comes from Jordan and Egypt.

Fig. 2 shows the energy imported and produced by the PT in 2010. The majority, 80%, was imported from different sources. This imported part consists of electricity, all types of fossil fuels, and other types of energy sources. The remainder, produced locally, consists of solar energy, wood, coal and olive cake. The exported energy to neighboring region this year was about 155 TJ (coal and wood), so the total energy available from different energy sources was about 55,863 TJ [10]. Details of what is imported, produced and exported are presented in Table 1. From this table, the amount of energy produced from petroleum derivatives accounted for about 53.2% of the needs of the local market of energy. Table 2 shows different types of energy sources imported by PT in physical units in year 2010 [10].

Table 3 presents the average annual price for the consumer for different types of energy sources in the Palestinian territories in 2010 [10].

3. Electricity sector

Connection of households in different parts of the PT to the electric grid increased in the last decade, from 96.8% in 1999, to 99.8% in 2010. However, a high percentage of households receive an interrupted power supply. Moreover, the electrical network suffers from high transmission losses; indicative of low quality supply. Table 4 shows the percentage of households connected to the grid in different years in the period of 1999–2011, while Table 5 shows percentage of number of hours of electricity services in both WB and GS, and for PT in general [11].

Fig. 1. Map of Palestinian territories

In PT, the electrical networks are considered distribution ones where the voltages through these networks ranges from 0.4 kV to 33 kV. The supply voltage from IEC to these networks is 22 kV or 33 kV [12].

There are two additional connection points to PT networks from Jordan and Egypt. The power capacity supplied from these two connection points is limited, where the connection point to Jordanian network is at Jericho in WB, while the connection point to the Egyptian network is at Rafah in GS.

The energy provided by the three sources does not meet the power needs of the PT. For example, the estimated demand of the installed capacity for the WB is around 820 MW, while IEC only provides approximately 720 MW of electricity. This shortage affects the development of infrastructure, halting economic

activities [13]. This encourages the exploration of alternatives to address these needs.

There are four companies providing electricity for Palestinians in the WB, and they are: Jerusalem District Electric Company, Southern Electricity Company, Northern Electric Distribution Company and Tubas District Electric Company. These companies purchase electricity from IEC and Jordan, and sell it to the Palestinians. In GS, the Palestine Electric Company fulfills this role, by purchasing electricity from IEC and Egypt.

The amount of power generated by the Palestine Electric Company in GS is very limited, and covers only a portion of what GS needs. The major part of the supply comes from IEC.

Fig. 3 shows the details of electricity purchased by different sources to PT electrical networks in 2010, while Table 6 details of monthly electricity purchased [10].

Table 7 presents quantities of imported and produced electricity in PT in the years 2006–2010 [10]. It appears that the imported quantities increase, while the produced part increases until the year 2009 where amount of fuel entered GS required for generation was limited by Israeli authorities. The generation station in GS worked for a limited period of hours and at part of its full capacity in this year.

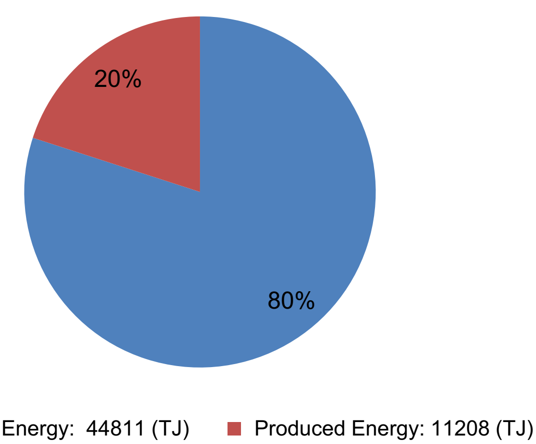

Fig. 2. Amounts of energy imported and produced in PT in 2010.

Table 1
Energy balance of Palestinian territories in TJ, 2010.

Energy flows	Energy products						Total
	Solar energy	Electricity	Petroleum derivatives	LPG	Olive cake	Wood and coal	
Primary production	4826	–	–	–	684	5697	11,207
Imports	–	14,972	23,950	5754	–	135	44,811
Exports	–	–	–	–	–	– 155	– 155
Total energy supply	4826	14,972	23,950	5754	684	5677	55,863

In the year 2010, the total imported electricity to the PT was 4158.8 GWh. The quantity imported (from IEC and Jordanian network) by WB networks was 2919.8 GWh, while the amount imported (from IEC and Egyptian network) by GS networks was 1239.0 GWh. The amount generated by Palestine Electric Company and fed GS networks was very limited, and its value was 305 GWh.

In the same year, the final consumption of electricity from different types of users was 3280.2 GWh [10]. This means that the energy efficiency during this year was 73.5%. This low efficiency was due to high losses in transmission and distribution, and due to unread consumed energy for street lightings, water pumping services and other municipal similar activities. Purported losses due to transmission and distribution accounts for about 15.6% of the total supplied energy.

For year 2010, Fig. 4 illustrates the amount of electricity consumption for different sectors in the PT [10]. It appears that industry consumption was low; it stands at about 10.6%. The majority of consumed energy went to households. Its percentage was about 63.3%. Agriculture, internal trade and services constitute the remaining sectors.

4. Household sector consumption

In the PT, households are considered the highest energy-consuming sector. Due to this fact, Palestinian Central Bureau of Statistics (PCBS) conducts a special household energy survey twice a year to shed light on different energy consuming facilities used in households, energy consumption, and behavior of this consumption.

Different statistical data on electricity and fuel consumption by households and patterns in the society by type of energy are included in the reports of the household energy survey.

Different data concerning household energy consumption is available for January 2011. Table 8 presents the average household consumption of different types of energy sources in January 2011 [11]. It is obvious from the table that the average energy consumption of different types is rather low. This also applies for electricity consumption. To illustrate the behavior of consumption in both WB and GS, Table 9 shows the average household electricity consumption for certain months in years 2010 and 2011 [11,14,15]. In January 2010, the per capita electricity consumption was 50.2 kWh (around 600 kWh per year). It is very low compared to neighboring countries, where the average annual electricity consumption per capita in the Arab world stands at about 3600 kWh [16]. This rate varies from state to state.

Table 3
Consumer prices for different types of energy sources, 2010.

Energy type	LPG ($/kg)	Kerosene ($/l)	Coal ($/kg)	Gasoline ($/l)	Diesel ($/l)	Oils and lubricants ($/kg)
Average annual price	1.73	1.68	2.47	1.8	1.67	4.96

Table 2
Imported energy (in physical units) in the PT for different types of energy sources, 2010.

Type of energy	Electricity (GWh)	Gasoline (10^6 l)	Diesel (10^6 l)	Kerosene (10^6 l)	LPG (10^6 kg)	Bitumen (10^6 kg)	Oils and lubricants (10^6 kg)	Wood and coal (10^6 kg)
Amount of energy	4159	172	476	1.8	122	11	18	19

Table 4
Percentage of households that connected to the electrical grid: January 1999, 2003–2005, and 2009–2011.

Indicator	1999	2003	2004	2005	2009	2010	2011
Percentage of households connected to the electrical grid	96.8	99.3	99.4	99.4	99.3	99.9	99.8

Table 5
Household percentage according to number of hours of electricity service, January 2011.

Region	Percentage for number of hours of electricity service:			Total
	Less than 16 h	17–23 h	24 h	
Palestinian territory	34.7	0	65.3	100
West Bank	0.5	0	99.5	100
Gaza Strip	100.0	0.0	0.0	100

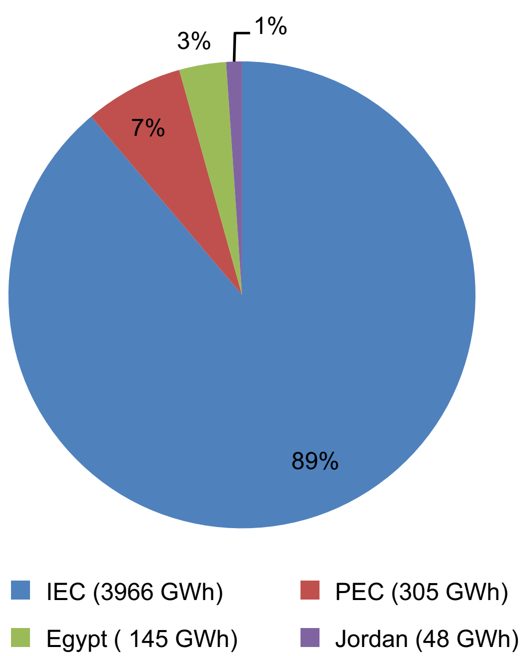

Fig. 3. Amount of electricity purchased from different sources by PT in year 2010.

Different factors are affecting the household electricity consumption in the PT. One cannot generalize provisions on energy consumption in the Palestinian case, but a trend that electricity consumption in summer months is greater than other months appears sporadically in different years. The main factors affecting this consumption are the availability of electrical supply throughout the entire day, availability of other types of energy sources that can be used as alternatives instead of electricity, popular use of air-conditioning systems in the previous years, and use of solar heaters in sunny months to obtain hot water instead of using electricity.

In PT, the use of solar heaters to obtain hot water is very popular. Different types and technologies are used for this purpose. The percentage of households that own solar heaters in the PT in January 2011 was 63.7%, and it was 67.6% for WB, while it was 56.4% for GS [11].

The type of energy used to obtain hot water depends on the month. Fig. 5 shows percentage of households that used different types of fuels for water heating in January 2011 [11], while Fig. 6 shows these percentages for June 2010 [15]. It is very obvious from Fig. 5 that in the winter months (January), electricity was the main source for water heating, where the weather is generally cloudy with low sunshine hours, whereas Fig. 6 illustrates that in the summer months (July), solar heaters were the main source for water heating, where the weather is sunny with high number of sunshine hours.

The results also indicated that 55.4% of households used gas burner for water heating, 35.5% used fast electric water heater,

Table 6
Purchases of electricity (GWh) in the PT from different sources for different months, 2010.

Month	Energy source				Total
	IEC	PEC	Egypt	Jordan	
January	347.4	35.2	11.30	5.7	399.6
February	300.8	26.7	11.5	5.1	344.1
Mach	339.7	21.4	12.8	6.4	380.3
April	271.0	18.1	11.9	7.0	308.0
May	297.9	19.6	12.1	6.4	336.0
June	318.3	16.6	12.1	2.0	349.0
July	347.2	19.7	14.5	4.3	385.7
August	426.8	21.9	12.3	4.4	465.4
September	338.3	33.7	12.6	3.7	388.3
October	328.9	35.7	11.0	3.1	378.7
November	302.2	23.3	10.8	0.20	336.5
December	347.1	33.0	11.8	–	391.9
Total	3965.6	304.9	144.7	48.3	4463.5

Table 7
Imported and produced electricity (GWh) in the PT in years 2006–2010.

Source of electricity	Imported and produced electricity (GWh) in PT in year:				
	2006	2007	2008	2009	2010
Imported electricity	3096.4	3188.3	3864.8	3982.9	4158.8
Produced electricity by PEC	345.3	417.1	426.7	500.7	305.0
Total	3441.7	3605.4	4291.5	4483.6	4463.8

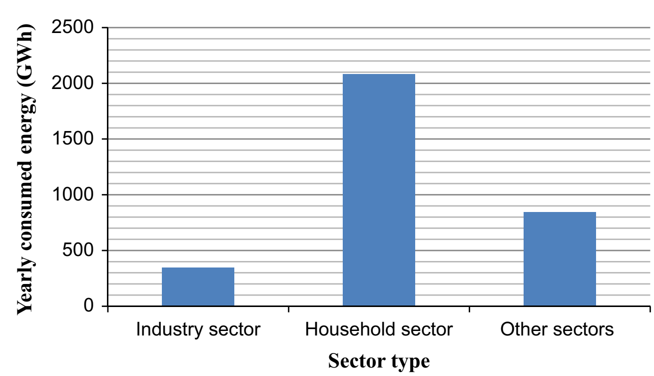

Fig. 4. Amount of electricity used by different sectors in PT in 2010.

Table 8
Average household consumption from different types of energy sources, January 2011.

Region	Average household consumption of energy					
	Electricity (kWh)	Wood (kg)	LPG (kg)	Kerosene (l)	Gasoline (l)	Diesel (l)
Palestinian territory	266	228	21	10	46	102
West Bank	256	313	24	20	77	113
Gaza Strip	286	75	15	7	16	19

Table 9
Household electricity consumption (kWh) in certain selected periods.

Period	Household electricity consumption (kWh) in		
	PT	WB	GS
January 2010	254	233	294
June 2010	250	267	217
January 2011	266	256	286

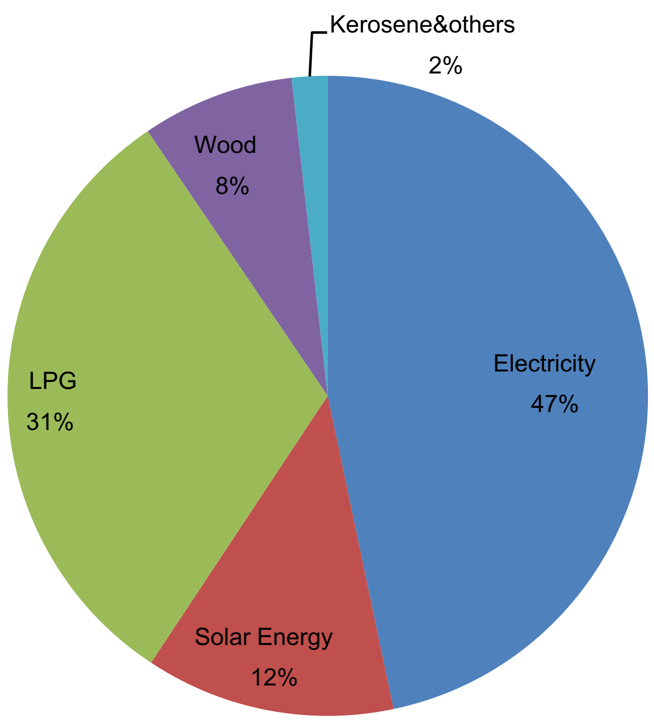

Fig. 5. Percentage of households that use different types of fuels for water heating in PT, January 2011.

while 20.6% used electric boiler [11]. Many households used more than one type of these heating facilities.

The results also indicated that 46.7% of households depended on electricity (electric boiler and/or fast electric water heater) as a main source for water heating, 31.2% of households depended on LPG, while 12.6% of households depended on solar heaters. The remaining used wood, kerosene or did not use any type of fuel for water heating [11].

Fig. 7 shows percentage of households that used different types of fuels for heating in the PT in January 2011 [11]. It is obvious that this percentage depends on region and the availability of different energy sources. In the WB, where LPG was available, the higher percentage was for this type of fuel, while in the Gaza Strip, the higher percentage was for electricity where citizens cannot easily obtain LPG.

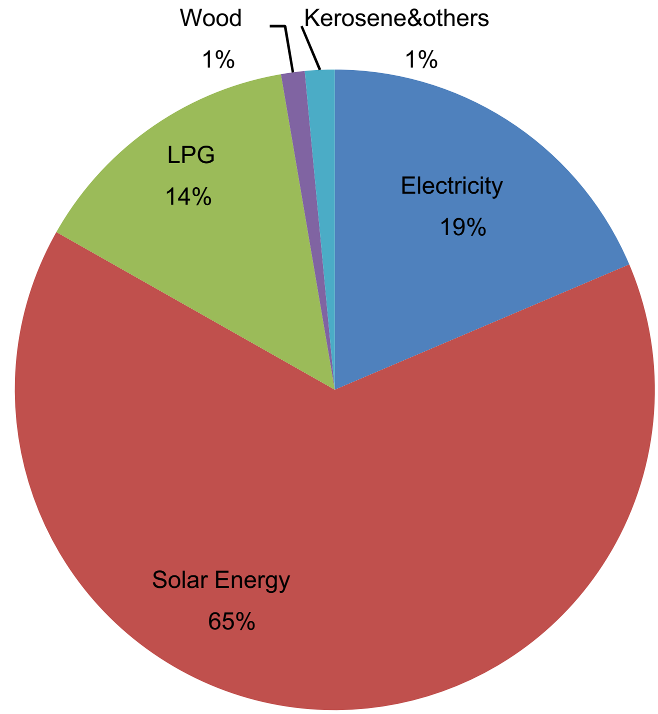

Fig. 6. Percentage of households that use different types of fuels for water heating in PT, January 2011.

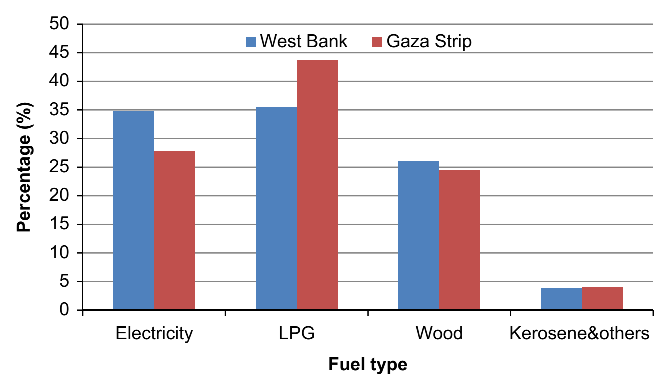

Fig. 7. Percentage of households that use different types of fuels for heating in WB and GS, January 2011.

Table 10 summarizes selected indicators of household energy consumption for January in years 1999, 2003–2005, 2009–2011 [11].

5. Renewable energy applications

On the Palestinian land, natural resources such as solar, wind, and biomass are available, with promising potentials at different sites. Unfortunately, this availability is not reflected on their contribution to the energy balance. One of the Palestinian authority's interests is investing in these resources to improve the reliability of the power supply and mitigate the environmental effects, while taking into account the economic factors and energy security issues. This will indeed lead toward a more independent Palestinian energy system. To achieve this purpose, large and small-scale renewable energy systems shall be implemented

Table 10
Selected indicators of household energy, January 1999, 2003–2005, 2009–2011.

Indicator	1999	2003	2004	2005	2009	2010	2011
Percentage of households connected to the electrical grid	96.8	99.3	99.4	99.4	99.3	99.9	99.8
Percentage of households having solar heater	63.8	70.3	68.7	67.2	59.6	61.6	63.7
Average household consumption of electricity (kWh)	264.6	268.0	264.7	256.0	275.0	254.0	266.0
Average household consumption of LPG (kg)	32.0	31.0	32.1	30.0	21.0	20.0	21.0
Average household consumption of kerosene (l)	11.9	17.0	23.2	22.0	24.0	14.0	10.0
Average household consumption of wood (kg)	86.5	259.0	207.2	236.0	287.0	209.0	228.0

throughout the PT. Despite financial and technical issues, the availability of natural resources and the required technology encourages the implementation of such projects.

Different authorities and non-government organizations (NGO) in the PT work in energy and environment sectors. These include Palestinian Energy and Environmental Research center, Palestinian Energy authority, different university research centers, and others. The Energy research center, one of the scientific centers at An-Najah National University, is one of the centers concerned with research and development in different renewable energy fields.

Authors of Ref. [1] conducted a study focusing on the calculation of an estimated percentage of the contribution of renewable energy generation for the PT's total energy consumption. They concluded that this contribution could replace about 25% of the required energy demand for the PT.

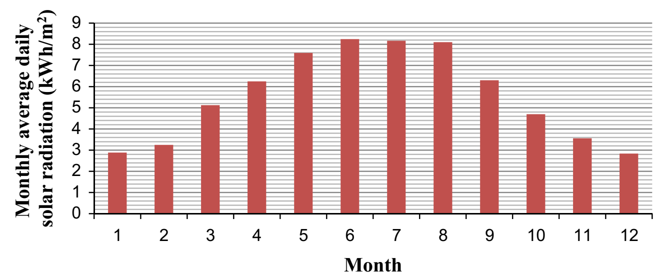

Fig. 8. Monthly average daily solar radiation in north of West Bank.

5.1. Solar energy

Palestine has high potentials of solar radiation with high sunshine hours throughout the year. The yearly average daily solar radiation on horizontal surfaces is about 5.6 kWh/m^2, while the total annual sunshine hours are about 3000 h [17]. These values are relatively high and receptive to the use of solar energy for solar water heating, Photovoltaic (PV) applications or other applications. Fig. 8 presents the monthly average of daily solar radiation incident on a horizontal surface in a location in North part of West Bank [18].

Different challenges are facing the implementation of PV projects, both on small or large scales. These challenges may limit the spread of this technology. Any solar energy project generally requires high financing and technological requirements, availability of highly qualified persons for design and installation, availability of space, and infrastructure for storage system, standby energy source if required, and connection to the grid. Obtaining finance for small scale standalone PV projects is usually easier. Success in these projects in the pilot scale will lead to more investment in larger scale projects, so the plan for investment in PV applications should begin from small projects.

5.1.1. Solar water heaters

Converting solar energy into thermal energy is one of the important applications of this type of energy. In addition to its use in PT to obtain water and space heating, it is also used for drying and preserving fruits and vegetables. In the PT, about 63.7% of total households have solar heaters. Its use had begun in the PT since 1970 [12]. The most popular type, which is widely used in the PT, is the thermosyphone open loop system. One of the reasons for its spread in the PT is the availability of its constituent materials in the Palestinian market. It is locally manufactured and installed, which lowers its costs. Its total cost is about $250 including installation (local market price). Usage of this system is sufficient to cover the daily requirement of hot water for a family of 6–10 members for a period of about 9 months out of a year. Other types of water boilers depending on electricity, gas or diesel with high fuel costs can be dispensed of during these periods. Actually, these types of solar heaters have low simple payback periods.

Use of solar heaters reduces household consumption of electricity, diesel and gas fuels. This is in turn considered a great advantage, since it reduces the dependency to obtain these fuels from Israeli companies.

5.1.2. PV applications

Different small standalone PV projects have been implemented under the supervision of Energy Research Center at An-Najah National University, while others have been implemented under the supervision of NGOs. These projects are intended for Palestinian remote rural areas in the West Bank, with rating ranges from 5 to 30 kWp for each. Atouf, Emnazeil, Yarza, Amkahel, Izbeq and Alsaeed villages are examples of rural areas that are electrified using PV standalone systems. These projects were installed under the supervision of the energy research center at An-Najah National University.

The implementation of these projects proves that it is feasible and possible to conduct such projects despite the different challenges it faces. In fact, this implementation requires different steps, beginning from the study of the community's needs, obtaining the technical information, preparing the designs and obtaining the needed funds, installation of equipment, and finally sharing the relevant information with the local community to enable them to operate and maintain these systems.

Hybrid systems that combine conventional and renewable energy resources are usually used to supply such isolated loads. Different benefits can be achieved by adopting this kind of technology for energy generation compared to a single renewable system. Reliability, energy security issues, and the environmental effects are part of these benefits [17,19–23]. The potential of renewable energy source in a certain location and availability of fuel for the conventional source determine the type of hybrid system adopted for certain applications at that location. Diesel generators are usually used as backup sources in these hybrid systems.

Microturbines can be used as backup sources instead of diesel generators in these PV hybrid systems, which make the utilization of such hybrid systems more attractive. Microturbines are relatively new generation technology. They are small, high

speed combustion gas turbines. Their outputs are in the range of 25–500 kW [24–27]. They produce both electricity and heat during operations [28–30]. Any microturbine is made up of turbine, alternator, compressor, combustor, recuperator and power electronics [31,32]. The exhaust gas from the turbine is allowed to pass through a heat exchanger (regenerator) for heat extraction, and this heat will be utilized for different purposes (heating space, boilers, cooling systems).

Previous demonstration regarding household consumption in PT illustrated the fact that during the winter months, 79.2% of households use electricity, LPG or kerosene for water heating (Table 10). Percentage of households that depend on solar heaters, wood or other types for water heating is about 20.8%. This is because solar radiation at these months has low averages. If a microturbine is used within a hybrid system to supply electricity to these households instead of a diesel generator, the energy required for water heating directly comes from the microturbine while it is running to supply the electrical load instead of using electricity to obtain this energy. So, using PV-Microturbine hybrid systems to electrify such loads will reduce the rating of the microturbine compared to diesel engine, and reduce the number of hours of operation of the microturbine and therefore, the natural gas consumption as a fuel source for the microturbine. Furthermore, the natural gas used as a fuel for microturbines is less polluting than diesel [33–39].

The Palestinian Energy Authority has prepared a strategy to raise the contribution of the renewable energy in the energy balance as an important part of the resource matrix, where Palestine needs a clean and more secure supply of electrical power. The Palestinian Energy Authority has developed a clear goal for the year 2020. In this plan, a 240 GWh of energy (at least) should be gradually attained to generate electricity from different renewable resources by 2020. This will be equivalent to 10% of the total power required by the PT [16,40].

As previously mentioned, solar water heaters are ubiquitous in the PT. Taking into account this fact and the aforementioned strategic plans, the dependence on renewable energy will reach 25% of the power produced by the year 2020 [40].

According to the strategic plan of the Palestinian Energy Authority, the 10% target in 2020 is equivalent to 130 MW, and it has been identified as follows: 45 MW on ground and rooftop PVs, 20 MW from concentrated solar power plants, 21 MW biogas from both landfill and animal waste, and 44 MW from both wind farms and small scale wind turbines. The implementation stages of this plan are divided into two phases [40]:

> The first phase (2012–2015) involves the generation of 25 MW by the various suggested sources. The first step in this phase, called the Palestinian Solar Initiative (PSI), has been launched. This initiative consists of three phases over a period of 3 years, from mid-2012 until mid-2015, and aims to set up small PV systems with a capacity of up to 5 kW for each project to be installed on the roofs of homes in order to realize a total of 5 MW at the end of three years. Each subscriber will attain a preferable electricity tariff for energy generated by the installed PVs according to the incentive bonuses set aside for this purpose.
>
> Other projects are also to be installed at this stage, covering other parts of this stage. Actually, an MOA was signed with the donor countries for the implementation of some of these projects. One of these proposals is to build a plant to produce electricity, with a capacity of about 550 kW using solar panels in the Jericho area (the first part of this project with a capacity of 300 kW has been launched on 1 October 2012; it is now connected to the network and can produce about 422 MWh per year and an amount of 290.6 t CO_2 can be saved accordingly each year). Another proposal is to build a plant to produce electricity with a capacity of about 360 kW using solar panels in the Tubas area (the first part of this project, with a capacity of 120 kW, has been launched on 2 June 2013, and it is now connected to the network). Building a power generating plant, depending on concentrated solar energy on the Egyptian side to provide GS with some of its needs of electrical energy is also covered in one of these proposals.
>
> The cost of the implementation of other projects in the first phase will be through the private sector investment, in-exchange of purchasing the electricity produced at a preferable tariff for each technology according to its type. Other incentives will be provided by the government in this field so that they are feasible to the investor.
>
> The second phase (2016–2020) in this suggested plan will commence after evaluating the first phase and the Palestinian market in terms of the application and use of renewable energy technology. This will open the door for private investors to invest in this sector via preferable tariff and incentives that will be approved by the government, which will turn be of immense help in realizing the potential target in 2020.

The implementation of the aforementioned stages is the responsibility of various parties and institutions involved in achieving the desired goals of this strategy. These parties are [40]: Palestinian Energy Authority, Palestinian Electricity Regularity Council, universities through energy centers, Palestinian Energy and Environment Research Centre, electricity transmission and distribution companies and private sector investors.

5.1.3. Other solar applications: greenhouses, solar desalination

Planting inside greenhouses is very popular in PT. This technology effectively utilizes solar energy, especially during the winter months, and can be used to plant many types of vegetables and flowers. On top of their advantages in increasing productivity, this technology manages to optimize the usage of water in irrigation due to its dependence on smart irrigation techniques. This agricultural adaptation has allowed the Palestinians to realize self-sufficiency in terms of vegetable production and consumption. This is actually very beneficial due to the fact that the average yearly rainfall in the PT is very small, being less than 1000 mm yearly, and in most cases, they are less than 500 mm [41]. Underground water sources are also very limited in the PT, so any measures that can save water are crucial to the PT. The PT also only has about a total of 60 days of rainfall a year, concentrated in the winter and spring seasons, which negates a continuous flow of streams. These factors negate the potential investment in the PT vis-à-vis the generation of any type of energy in this field.

The water in GS is characterized by high degrees of salinity and scarcity of resources, which makes solar desalination a vital technology in this regard. In fact, more research should be performed in order to study the feasibility of implementing this technology in the PT.

5.2. Wind energy

The technology of wind energy has seen rapid development in recent times. Different pre-technical and economic studies should be performed before a decision to implement any wind project is made [42–45]. This also requires detailed studies regarding the potential of wind at the specified location. These studies shall involve several years (more than 5 years) of wind speed and direction measurements in order to guarantee a more reliable assessment. Distribution of wind speeds, energy available in wind,

and the appropriate type of wind turbine are studies to be performed, depending on these meteorological data.

Palestinian meteorological department and energy research center of An-Najah National University conducted such measurements for wind in different locations, but unfortunately, this was for limited periods in some cases, and in other cases, the measured data were incomplete for the entire period of measurements.

Table 11 shows the monthly and the annual averages of wind speeds for locations in north (Jenin), middle (Ramallah) and south (Hebron) of WB. Table 12 shows annual averages of wind speeds for the period of 1998–2010 [10]. The wind speeds are very sensitive to location and height. The averages presented in the tables are low, but are actually not reflective of the actual averages in certain locations in these regions, since the locations of the installed meteorological stations are usually selected according to certain considerations. The data for wind speed that displayed in Table 12 are exactly as displayed in the reference. It seems that the data presented in this table are contradictory; in certain years, the averages are small, while the averages for the others are duplicated compared to the years of small averages. In fact, the locations of the aforementioned meteorological stations are usually selected according to the availability of the space specified by the meteorological department installed at these stations. The locations are not selected according to the possibility of high potentials of wind speeds at certain sites. For certain cases, some of these stations were firstly placed in open areas, but after that, new buildings have been established near these stations. Actually, these new buildings may affect the readings of some of the sensors installed in these stations, especially wind speed sensors. In fact, the data of wind speed obtained by these stations are indicative of the potential of wind in these areas, but cannot be utilized for design of wind energy systems. For design purposes, the location should be carefully specified, where the height of the sensor should also be taken into account.

Table 11
Monthly average wind speed (km/hr.) in the three locations in WB for different months, 2010.

Month	Monthly average wind speeds (km/h) in:		
	Jenin	Ramallah	Hebron
January	6.6	9.4	8.3
February	6.9	10.4	9.4
March	6.8	10.8	9.9
April	7.5	10.2	9.0
May	8.2	12.4	9.5
June	8.8	12.5	10.2
July	8.4	13.7	10.5
August	7.7	11.3	9.2
September	6.7	11.8	9.6
October	5.4	9.0	8.1
November	3.6	7.0	6.8
December	3.1	10.1	17.7
Annual mean	6.6	10.7	9.9

Different meteorological stations were also installed in specific locations in the three regions of the WB. A meteorological station had been installed in district of Hebron in the south part of WB at a specified location (Alahli Hospital) in order to study the potential of wind speeds at this location. The annual average observed is higher than the averages displayed in Table 12; it is about 6.2 m/s [18]. In Ramallah district in the middle of WB, a meteorological station had been installed by the energy research center at An-Najah National University in Al-Mazra'a Al-Sharqiyah. The annual average recorded was about 5.52 m/s. In the north part of WB (Nablus district), a meteorological station was also installed by the energy research center. The annual average for this station was about 4.35 m/s. It is known by local citizens living in these areas that the wind speed potentials in these areas are high prior to the installation of the meteorological stations at these sites.

It is encouraging to use small wind turbines to electrify sites located far from the grid and have high potential of wind speeds, especially if they are used within a hybrid system with PV. Authors of Ref. [17] conducted a techno-economic study to electrify a remote house in Palestine, utilizing renewable sources. The location chosen for their study has a yearly average daily solar radiation on horizontal surface that is equal to 5.6 kWh/m^2/day, while yearly average wind speed equals to 5.5 m/s. They tested different scenarios to choose the most feasible one. Their results indicated that the most economical scenario is the one consisting of PV, wind, diesel generator and a battery system. The cost of energy in this scenario is 0.281$/kWh.

Another attractive and feasible application for small wind turbines is to use them for water pumping, especially for rural areas where diesel generators are used for this purpose. These water pumps are used to pump water from a well to a storage tank. The remote sites intended to be served by this technology are usually far from the existing grids, so installing a grid at these sites is rather costly. Using wind turbines to replace diesel generators is advantageous, especially for remotely located sites, due to the fact that diesel is rather expensive in the PT, and transferring them to these remote sites is difficult and risky, which further increase its price. Furthermore, this will save the environment from different pollutant emissions emitted from diesel fuel. Sometimes, a hybrid system consisting of wind turbine, PV system and a backup source can be used for this purpose.

For the three locations in WB, the data available for wind speeds from NASA's surface meteorology and solar energy was used to compare with measured data by the installed meteorological stations. The NASA's data is an average over an entire area of a cell of $1^\circ \times 1^\circ$ [1,46]. This average may not reflect the actual average of a specific location within this grid. So, NASA's data are indicative of wind speed and supplements the measured data, but for the actual assessment, NASA's data are incapable of replacing the ground measurement data. NASA's data indicates that the average of wind speed over 21 years period (1984–2004) for Hebron was 3.1 m/s, for Ramallah it was also 3.1 m/s, while for Jenin it was 3.2 m/s. For Gaza, no surface measurements are available, while NASA's data indicates that wind speed average for the same period was 3.35 m/s [47]. Gaza Strip is located on the

Table 12
Yearly average wind speed (km/h) for three locations in WB for years, 1998–2010.

Station location	Yearly average wind speed (km/h) in the year													
	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Average
Jenin	3.9	9.0	8.3	7.9	–	5.4	3.8	3.4	–	4.8	6.7	7.0	6.6	6.1
Ramallah	5.0	–	–	–	–	7.8	–	–	–	8.5	8.5	11.0	10.7	8.6
Hebron	5.1	6.4	12.8	12.5	-	8.6	10.4	12.1	–	6.3	4.4	6.0	9.9	8.6

Mediterranean Sea coast; so installing off-shore wind farms are viable.

A large wind energy project in the PT has been launched 3 years ago in Alahli hospital in Hebron. The purpose of this project is to install a large wind turbine (330 kW) to provide the hospital with more than 40% of its energy needs. The cost of this project is about 1.63 million dollars [48].

5.3. Bio energy

In the PT, citizens in rural areas are dependent on agricultural and livestock breeding, which are ripe for biomass energy sources. People living in these areas can benefit from this type of energy by burning wood and agricultural waste for heating and cooking purposes as traditional method, by burning these wastes for electricity generation, by obtaining biogas for home uses, or by obtaining biofuels to be used as a vehicle fuel.

Obtaining biogas from biomass (animal waste or agriculture residues) is a well-known technology throughout the world. Digesters are used for this purpose, where methane gas is the product of the biological process occurring in these digesters [49]. This technology is ideal for the Palestinian case, especially in rural areas, since huge amounts of biomass are available throughout the year, and it is easy and economical to build a digester, especially with the limited space required to install. These factors make it a rather reliable energy source in this context. Building small digesters in rural areas at the locations of animal farms helps in reducing the cost of transferring animal wastes to other locations, where digesters are built.

The financial and technical challenges that face the development of this type of energy sources are fewer than those that face other types of energy sources. Digesters help rural communities dispose the huge amounts of organic residue that might precipitate different environmental problems by utilizing and converting these residues into valuable materials (biogas). Furthermore, the product of the digestion process can be used as fertilizers for agricultural purposes. There are quite a number of digesters that are built as research projects in the northern part of WB for the purpose of investigating investment viability of this field. The results are positive, where a digester depending on animal dung of 3.5 m^3 volume can save a family about 1000$ per year [50]. Results of another digester depending on solid waste materials indicated that 0.11 kg of biogas can be produced by 1 kg of organic waste [51]. In this study, it was concluded that an amount of 4–5 MWh of electricity could be generated per day by utilizing large scale digesters in Zahret Alfinjan Landfill in Jenin City, north of West Bank. An amount of 400 t/day of solid waste, with about 50% organic fraction with no hazardous materials is received by this landfill.

The produced biogas can be used as a fuel source for microturbines [26]. As previously mentioned, these microturbines can run as a backup source in PV hybrid systems, or as a standalone source. This feature makes them more attractive compared to diesel generators, especially in rural areas where provision of diesel fuel is scarce.

The animal waste is a harmful pollutant for the water supply in the Gaza Strip, due to its status as the most densely populated region in the world. Therefore, open lands that are available for the disposal of this waste are rather limited, and the improper handling of these wastes might cause them to pollute the water supply. Using digesters offers additional benefits that prevent these animal wastes to contaminate the water supply in addition to their previously mentioned benefits [52].

Agricultural residues, food processing wastes and organic municipal waste constitute the largest portion of biomass sources. Different means exist to utilize this biomass for the purpose of generating energy. Gasification is one of these means that enables the generation of electricity, utilizing high content heat of these residues [53]. Biochemical or thermochemical processes are the other means used to extract energy from these residues in the form of biodiesel. In PT, there exist huge amounts of these residues that can be treated to produce both electricity and biodiesel for the rural and urban areas.

Depending on the data they obtained from Palestine Central Bureau of Statistics regarding the number of cattle, goat and sheep, and the estimated amount of manure produced from these live stocks, authors of Ref. [1] concluded that a total of 4.5 million m^3 of biogas per year can be generated via digesters built specifically for this purpose. This amount of biogas is sufficient to meet cooking needs for about 10–20% of the rural population as per their conclusion. Results of the same study indicated that 2 TJ/year of heat energy can be obtained from the total amount of agricultural residues and food processing wastes in PT. Biomass gasification can be used to extract this heat energy for electricity production.

5.4. Geothermal energy

The expression ‘ geothermal energy’ is usually used to indicate the heat harnessed from underground sources such as hot steam, water or rock found a few miles beneath the earth's surface or down even deeper to the extremely high temperatures of molten rock. But, it may also be used to indicate the heat extracted from shallow ground [54]. The shallow ground or depths through ground for several meters distance under the surface of the ground usually maintains nearly constant temperatures between 10 °C and 16 °C throughout the year, irrespective of external temperature variations. This top layer is heated by solar energy during the summer, and releases that energy and cools during the winter. In this context, geothermal heat pumps can tap into this resource and utilize this stored energy to heat and cool buildings. By this technology, the energy is transferred between the building and the ground, utilizing the temperature gradient between the two [54–58]. Utilizing this technology can significantly lower the energy consumed by a building, since a high percentage of building energy consumption is used for cooling and heating. In a Palestinian context, this will lower the dependency on external energy sources. Furthermore, this technology lowers operational costs, and significantly reduces pollutant emissions.

A 23 kW geothermal heating and cooling system has been installed in a residential complex in Ramallah, and it is the first project in the Mediterranean region. This project has been designed and implemented by MENA geothermal company. It is also the first company in the region that utilizes this technology. This system is currently being monitored, and it is expected to reduce operating costs by about 67% (from 8100$ per year to merely 2700$ per year) for it to maintain an all-time comfortable room temperature. The initial cost of this system was around 48,000$, compared to a 23,000$ for a conventional one. This means that the simple payback period for this system is about 4.2 years. As a result of running this system, the reduction in electrical consumption is expected to be around 28,000 kWh per year, and this in turn reduces the CO_2 emissions by 7 t per year [59].

Geothermal systems exist in different types. The most appropriate type for the PT is the vertical closed system, where pipes are installed vertically due to the limitation of the land area, especially in residential areas.

5.5. The effect of reduction in the cost of renewable systems on present and future plans

The decrease in the cost of the PV panels, as well as other renewable systems, will surely enhance the availability of these

systems in the markets. This is also true in the Palestinian context. The effect of the reduction in the PV cost on the cost of energy production has been analyzed in a study done by Ismail et al. [60]. This study has been carried out for the Palestinian case, with the express purpose of designing a hybrid system consisting of PV panels and a microturbine as a backup source. It has been found that a reduction in the PV cost by 40% will decrease the COE from 0.284$/kWh to 0.260$/kWh, while a reduction in the cost of the PV panels by 60% will decrease it to 0.244$/kWh. In a similar study, Daud and Ismail [17] found that the cost of energy production will decrease from 0.281$/kWh to 0.247$/kWh when the PV panels cost is assumed to decrease by 40%. This study has been also carried out for the Palestinian case, but the analyzed hybrid system consists of PV/wind and diesel generator as a backup source. It has been also found that the PV contribution in the hybrid system will increase by 40%. These studies and others illustrated that the usage of the PV systems will increase as the cost of the PV panels decreases, and consequently, the cost of energy production will decrease. Furthermore, in the strategic plan for renewable energy in Palestine, certain funds have been allocated for each item, depending on its present costs [40]. Any future reduction in the costs of each unit of these items will surely increase the number of units of each of these items, and consequently their deployment in the local community.

6. Energy conservation strategies

Adopting energy conservation strategies shall be one of the measures used to reduce the total energy consumption in different sectors. Improvement of energy efficiency in public utilities, as well as in residential, commercial and industrial sectors will surely lead to a reduction in energy consumption. The amount of purchased energy will be decreased accordingly. The investment costs associated with implementing these strategies and its payback periods are usually low. This fact is indicative of a stressful situation vis-à-vis the adoption of a clear energy conservation policy.

Different measurement and audit procedures shall be held in order to achieve this. This includes energy auditing for lighting, motors, distribution networks, water heating, refrigeration, air-conditioning and other electrical appliances. The presence of public awareness and regulations that control the quality of different electrical appliances in terms of their consumption and energy efficiency will most certainly help. One of the important regulations is to create energy labels for different electrical appliances; especially refrigerators that help consumer select a model that consumes the least amount of power. For increasing public awareness, different available multimedia can be used. TV, press, personal communication, video films, as well as brochures, boosters, courses in schools and exhibitions are examples of mediums that can be used for this purpose.

A detailed study held for the Palestinian case [12] showed that a reduction of 15% of the total energy consumption is possible if their suggested measures are adopted.

Another field that can significantly reduce the energy consumption in buildings is the design of energy efficient buildings that maximizes utilization of natural ventilation and solar heating. A design and implementation for an ultra-energy efficient building in the PT showed that the energy demand for heating purposes in winter can be reduced by more than 70%, while a cooling system in the summer is limited for few days every year. The building architecture design includes building sitting, building envelope performance, solar chimneys heating and cooling performance, and natural and forced ventilation by solar chimneys [61].

The number of air-conditioned spaces in the PT is rapidly increasing during the past years. Selecting a proper thermal insulation materials for the exterior walls in the air-conditioned buildings, and calculating the optimum thickness for this insulation will reduce the energy consumption and environmental impact [62].

7. Energy projects waiting implementation

The Palestinian territories have one of the fastest growing populations in the world. The natural increase rate in the PT was 2.9 in 2011; it was 2.6 in WB and 3.3 in GS [63]. This fact, as well as the goal to reduce the reliance on external sources, emphasizes on more and more investment in the energy sector. In addition to the renewable energy strategic plan as previously mentioned, other energy projects are within the plan of the various parties working in this field in the PT. Part of these energy projects will be illustrated later in this section.

Palestine Investment Fund (PIF) is one of the institutions that work to develop the energy sector in the PT. In cooperation with local and regional companies, PIF is working to launch different energy projects. PIF works with other partners to develop Gaza's natural gas field off the coast of GS, and is currently working with a pilot group of local and regional companies in order to develop a power generating station in the WB.

7.1. Natural gas Gaza project

In year 2000, two natural gas fields with a total capacity of around 30 billion m^3 were discovered in GS. The first is Gaza Marine field, located entirely within the Palestinian territorial waters, which is the largest. The second is the Border field, which is considered an extension of the Noa south field, located in Israeli territorial waters [64].

The development process of Gaza marine field has faced a number of obstacles that prevented its completion. The effective Israeli control over Palestinian territorial waters has prevented exports of this gas to the world market. The development and construction of transportation pipelines require several procedures and approvals from the Israelis, which the developers were unable to secure so far. These obstacles also prevented the exploitation of the discovered gas from the local market.

The Palestine Investment Fund prepared a long term strategy regarding the development of this gas field. This strategy is based on utilizing the extracted quantities for the production of electricity, and meeting the needs of the Palestinian market. This requires construction of generating stations in both WB and GS. In case there is a surplus, it will be exported to international markets. This strategy involves expanding the power plant currently operating in GS, as well as accelerating the establishment of two power stations in WB, with a total capacity of 1250 MW [64]. This strategy will lead to the realization of the concept of energy security of Palestinian Territories, as well as the preservation of the environment through the use of natural gas in electricity production, as natural gas is less of a pollutant compared to other fossil fuels [37]. Furthermore, it will open new prospects for investment in the energy sector, which will enable the private sector to invest and receive good financial returns.

This strategy requires a number of steps in order for it to be implemented at various levels, so that its implementation is viable. The following are parts of these steps: concerted efforts of all parties involved in the project, the implementation of all parts of the strategy in parallel, key role of international institutions through the provision of financial and technical support for its implementation, political and international support so as to prevent disabling the project, and close cooperation between the

private sector and the public sector for the implementation of the different elements of this strategy.

7.2. West Bank electrical power generation station

In 2010, PIF, in partnership with a group of investors, founded the Palestine Company for power generation as a public limited company (West Bank power station). The company has an access to initial approvals required from the Palestinian Energy Authority for the project. In collaboration with the Energy Authority, the company is working to prepare a comprehensive feasibility study for the project, including specifying the most appropriate location for the station and its productive capacity. This generation station will be operating on natural gas, with a generation capacity around 200 MW [64].

It is expected that this project works will strengthen the Palestinian economy by enhancing its reliance on its own resources, particularly with regard to energy resources. This project will create new job opportunities via construction and operation processes. On the other hand, this project will supply electrical power for the Palestinian people at lower prices, due to the economical angle where the energy imports are invariably reduced.

8. Conclusions

The Palestinian energy requirement increases, especially electricity, while most of the available energy sources are imported from neighboring countries. The electrical supply from different sources is really inadequate, which forms an obstacle beyond any development in the PT. Different times throughout a year, there are shortages in the power supply, while in GS, 100% of consumers in the last 2 years have electricity service for less than 16 h/day.

High energy losses, limited investment and high prices are features that characterize the electricity sector. To eliminate these problems and decrease their effect, the following priorities shall be abided by: rehabilitation of the electrical system, promotion and development of renewable energy sources, and the adoption of energy conservation strategies.

Investment in renewable energy systems in the PT will indeed reduce the reliance on neighboring countries for its needs from electricity and fossil fuels. Different financial and technical challenges and political impediments face any economic activity in the energy sector in the PT. The fact that different renewable energy applications can be locally initiated makes part of these challenges less relevant. These small project initiatives overcome the political and geographical limitations; furthermore, the costs of these small-scale projects are not too high, which makes it easy for it to be financed by local or foreign funding. Success in these projects may encourage more investment in subsequent projects. This stage is salient in establishing the independence of Palestine vis-à-vis energy supplies. The reliance on internal energy sources will also serve to stabilize the lifestyle of Palestinians, and increase the economic growth for Palestinians living in different areas, especially in remote areas, where the presence of energy source enables them to build their own economy. The provision of energy sources for remote areas enhances the survival of the local population in their lands, as they feel that their respective lands are always under the threat of confiscation.

As demonstrated previously, the Palestinian territories possesses good potentials for different renewable energy sources, mainly: solar energy, biomass and wind for specific sites. Investing in these fields is bound for success.

For investment in the energy sector, it is required to adopt recent energy policies resulting in strategies and action plans that are directed to encourage the exploitation in renewable energy, as it has become an urgent need. The return will be multi-tiered; especially for economic, political and environmental factors in the PT. International technology and expertise in this area shall be effectively utilized before settling the locally related industries. The next step is the gradual phasing out of foreign expertise, in order to reduce the dependency of the community on imported materials or foreign expertise. The realization of these factors will ensure the creation of more job opportunities for the Palestinians.

The lack of awareness of the importance of the use of renewable energy sources has had a clear impact on the limited spread of these sources in the Palestinian society in some other cases. Great responsibility in this direction lies on the competent ministries, civil society organizations, and NGOs. The role of these establishments is to prepare for workshops with the responsible authorities in cities and villages, and to establish awareness campaigns in schools and rural areas and communities. Awareness campaigns may include the construction of pilot models in different locations to train citizens. Actually, more and more shall be done in order to change the culture of citizens in terms of the importance of the inclusion of renewable energy sources in use.

The absence of a general energy policy for developing renewable energy resources and adopting energy efficiency standards is still a barrier adversely affecting the spread of renewable energy technology in the PT. For more exploitation in this field, the presence of such policy is imperative. This plan shall involve the required regulations, standards and provisions that control and regulate the investment in this field, incentives, financing strategies that encourage investment in this field, and adopting an electric tariff linked to time and/or tariff linked to base and peak loads.

An obvious reduction in energy consumption can be achieved by adopting different energy conservation strategies. Improvement of energy efficiency in different electrical sectors will surely lead to this reduction in energy consumption. Measurement and audit procedures shall be held in order to achieve this. The investment costs associated with implementing these strategies are usually low, with small payback period times. This fact is deemed to be suppressive towards the adoption of a clear energy conservation policy.

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